

# FORCED FLOW FLAME SPREADING TEST 1

(FFFT-1)

*Combustion Experiment*

*It is your concern when your neighbor's wall is on fire.*

Horace, poet  
*Epistles*

## INTRODUCTION

The first **Forced Flow Flame Spreading Test (FFFT)** studied flame spreading in a low-speed air flow environment.

Information from this experiment will be used to design fire safety systems for aircraft, the Space Shuttle, and the International Space Station.

The first Forced Flow Flame Spreading Test was conducted aboard the Space Shuttle *Columbia* during flight STS-75 of the third United States Microgravity Payload (USMP-3) mission. The second FFFT experiment was conducted aboard the Russian Space Station during the *Mir* Increment 2 mission.

For information about similar experiments, see the Comparative Soot Diagnostics (CSD) experiment and the Radiative Ignition and Transition to Spread Investigation (RITSI) which were also conducted aboard this flight. Also see the Candle Flames in Microgravity (CFM-1), the Smoldering Combustion in Microgravity (SCM), and the Wire Insulation Flammability (WIF) experiments which were conducted aboard the Space Shuttle *Columbia* during flight STS-50 of the first United States Microgravity Laboratory (USML-1) mission. Also see the CFM-2 experiment which was conducted during the *Mir* Increment 2 mission and the Opposed Flow Flame Spread (OFFS) experiment which was conducted during the *Mir* Increment 4 mission.

## THE SCIENCE

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They are wild and unpredictable. Disregarding life and property, forest fires rage out of control, destroying everything in their path. The spreading flames burn hot and intense, consuming all available fuel. Sudden gusts of wind can cause walls of flames to roar through a valley, bushwhacking firefighters.

On the other hand, logs burning in a fireplace appear harmless and charming.



The difference is control. In a fireplace, the flames are contained by fire-proof materials. Smoky combustion products are removed through the chimney. A screen prevents stray sparks from igniting surrounding fuels, such as furniture and carpeting.

Still, even in this controlled environment, fire cannot be taken for granted. The most efficient fireplace leaves some of the fuel unburned and much of the heat goes up the chimney instead of heating the house.

The purpose of controlling combustion, therefore, is extracting energy from fuel, burning fuel efficiently to reduce waste and pollution, and preventing the injury and destruction of fires

To improve our ability to control fire, scientists study the details of flames, including flame ignition, flame spread and flame extinction.

One of the most important and complicated parts of a flame is the motion of air. Air motion, or **convection**, brings fresh oxygen to the flame, carries away the combustion products, and determines the distribution of heat.

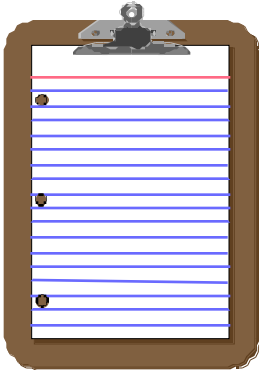
Gravity plays a major role in moving air around a flame. When air is heated by a flame, the hot air becomes lighter and is displaced by cooler air. The hotter the air, the faster it moves upward. The air motion caused by gravity and a temperature difference is called **buoyant convection**.

On Earth, buoyant convection normally moves air at the rate of approximately *one foot* per second, sometimes higher. Scientists know the most important effects of air motion occur at speeds between two and four inches per second, but these air speeds cannot be reached on Earth. In the microgravity environment, however, scientists can study flames in air moving as slow as *one inch* per second.

The Forced Flow Flame Spreading Test studied the effects of air flows on flames. Slightly different versions were conducted aboard the Space Shuttle and the Space Station *Mir*.

## THE OBJECTIVES

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To identify the effect of low-speed air flows on the flammability, ignition, flame growth, and flame spreading behavior of solid fuels burning in microgravity.



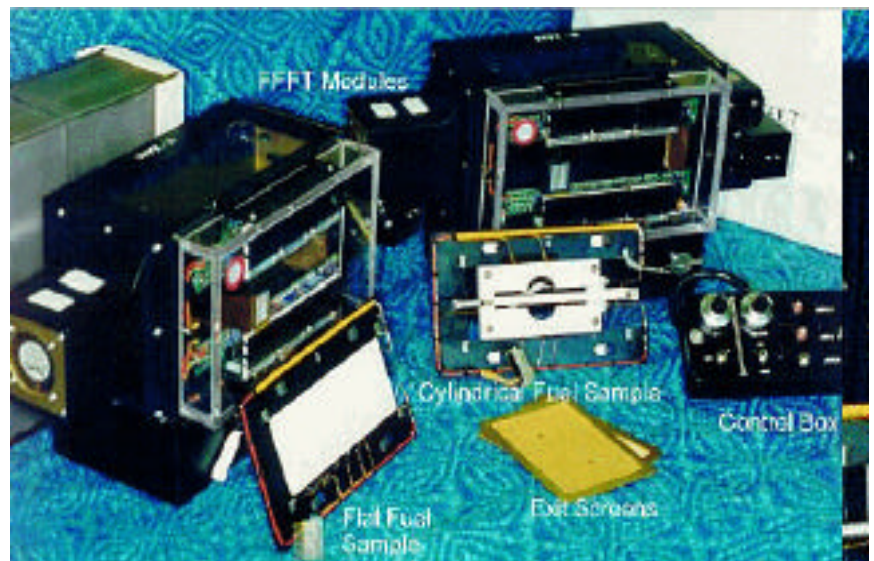
To identify the effect of fuel temperature, thickness, shape, and fuel material on the behavior of spreading flames.

## THE HARDWARE

The hardware consisted of two test modules which were miniature, low-speed wind tunnels. Each metal box had an inlet for measuring air speed and an outlet for the adjustable speed fan.

A small mesh screen separated the test section from the inlet and outlet sections. The mesh screen controlled the air flow, absorbed the flame's heat, and prevented by-products such as soot from escaping.

Each module included a hand-held control box to manage all of the operations.



*The FFFT hardware, including two wind-tunnel modules, flat sample, tube sample, exit screens, and control box.*

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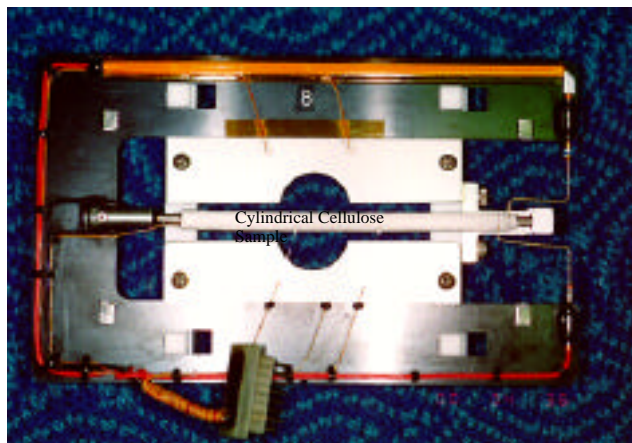
The experiment included two types of fuel samples.

The first fuels were ten flat samples of paper, or cellulose, having the same thickness. During the experiment, the samples were parallel to the air flow.

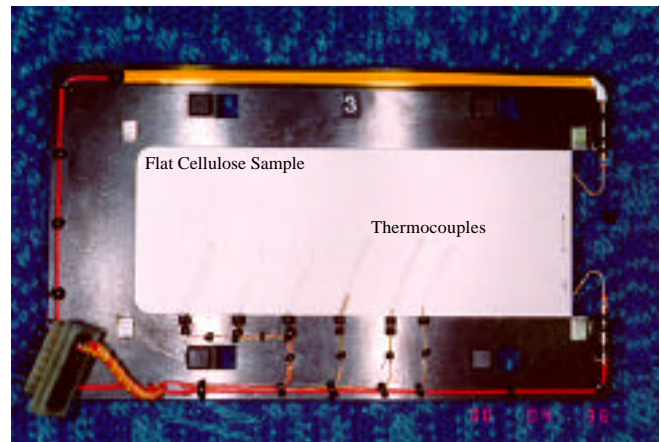
The second fuels were five tubes of paper, or cellulose, formed around a metal wire core that was heated to different temperatures before ignition.

Each sample was mounted on a steel card with a temperature-sensing device and a hot-wire igniter. Fuel samples were installed and removed through a window in the front of each module. Temperature-sensing devices, or thermocouples, near and inside each fuel sample, measured fuel and flame temperatures.

The control box located outside the Glovebox allowed the astronaut to conduct the test while video and 35 mm cameras recorded the results.



*Paper tube sample with igniter wire on right.*



*Flat paper sample with igniter wire on right end.*

## THE EXPERIMENT

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Pilot Scott Horowitz and Mission Specialist Jean-Claude Nicollier conducted the experiments.

The experiment measured flames spreading in air flow speeds ranging from one-half to four inches per second. Fuels were tested at different air speeds, fuel thicknesses and fuel shapes.

Ten flat paper samples were tested and the effect of air speed was recorded. Five paper tubes were tested; the effect of air speed and fuel temperature were recorded.

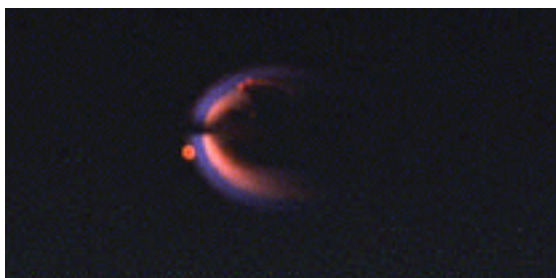
After setting up the equipment in the Glovebox and positioning the cameras, each test required the following steps:

1. Install a fuel sample into the module.
2. Seal the module and the Glovebox.
3. Set and start the air speed.
4. Heat the sample, if required.
5. Ignite the sample.
6. Record the combustion on video and film.

In four tests, gas samples were taken from the air stream. For some tests, video images were transmitted to Earth so researchers could fine tune the experiment.

## THE RESULTS

After the mission, scientists analyzed the film and video images to measure the size, brightness, and shape of the flame. They also studied the rate at which the flame spread over the fuel. They found that as the air flow speed increased, the flames became longer, hotter, and spread faster. In addition, the paper tube samples burned faster when they were heated before ignition.



*Flame spreading over flat cellulose sample.*



*Flame spreading over cylindrical cellulose sample.*

## THE CONCLUSIONS

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The first Forced Flow Flame Spreading Test was considered successful. The results of the paper sheet tests agreed with the scientists' computer simulations. The results of the paper tube tests provided information for developing computer simulations.

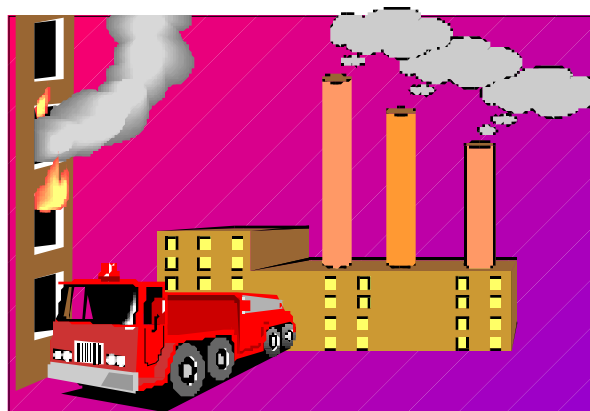
By comparing the experiment results to the computer simulations, the scientists can determine the accuracy of their theories on the effect of air flow on spreading flames.

## BENEFIT TO QUALITY OF LIFE ON EARTH

Flame spreading is a basic combustion process affecting the engineering of fire prevention, detection, and fire fighting practices. Understanding air motion is an important factor in rates of flame spreading and material flammability.

The experiment results and computer simulations will increase our knowledge of the way materials burn and will contribute directly to fire safety aboard spacecraft.

On Earth, a better understanding of the way flames spread will contribute to improved building designs and materials which reduce the risk of fire.



## FUTURE WORK

The results of FFFT-1 provided information about the behavior of a simple fuel in low-speed air flows. A second experiment continued the study aboard the Russian Space Station *Mir*. Using hardware designed for *Mir*'s environment, FFFT-2 tested additional fuel samples.

When the International Space Station is completed, additional fuels and air mixtures will be tested. In the mean time, scientists are continuing to improve the details of the flame spreading computer simulations.

## FOR ADDITIONAL INFORMATION



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